Analysis of Radiosonde and Ground-Based Remotely Sensed PWV Data from the 2004 North Slope of Alaska Arctic Winter Radiometric Experiment

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ABSTRACT

During 9 March–9 April 2004, the North Slope of Alaska Arctic Winter Radiometric Experiment was conducted at the Atmospheric Radiation Measurement Program's (ARM) "Great White" field site near Barrow, Alaska. The major goals of the experiment were to compare microwave and millimeter wavelength radiometers and to develop forward models in radiative transfer, all with a focus on cold (temperature from 0° to −40°C) and dry [precipitable water vapor (PWV) < 0.5 cm] conditions. To supplement the remote sensors, several radiosonde packages were deployed: Vaisala RS90 launched at the ARM Duplex and at the Great White and Sippican VIZ-B2 operated by the NWS. In addition, eight dual-radiosonde launches were conducted at the Duplex with Vaisala RS90 and Sippican GPS Mark II, the latter one modified to include a chilled mirror humidity sensor. Temperature comparisons showed a nighttime bias between VIZ-B2 and RS90, which reached 3.5°C at 30 hPa. Relative humidity comparisons indicated better than 5% average agreement between the RS90 and the chilled mirror. A bias of about 20% for the upper troposphere was found in the VIZ-B2 and the Mark II measurements relative to both RS90 and the chilled mirror.

Comparisons in PWV were made between a microwave radiometer, a microwave profiler, a global positioning system receiver, and the radiosonde types. An RMS agreement of 0.033 cm was found between the radiometer and the profiler and better than 0.058 cm between the radiometers and GPS. RS90 showed a daytime dry bias on PWV of about 0.02 cm.

1. Introduction

Although many years of research and experiments have focused on radiosonde measurements of humidity, many recent experiments have been conducted, primarily because of the importance of humidity to the modeling of radiative transfer (Clough et al. 1999; Revercomb et al. 2003; Ferrare et al. 2004). In forward model studies, calculations based on radiosondes are compared to both infrared and microwave radiometer observations (Westwater 1997; Westwater et al. 2003; Liljegren et al. 2005; Mattioli et al. 2005a; Hewison et al. 2006). Thus, the accuracy of radiosonde observations has a direct impact on the evaluation and development of forward models, as well as in the evaluation of radiometers themselves. Remote sensor measurements of precipitable water vapor (PWV) have also played an important role in the evaluation of radiosonde accuracy (Clough et al. 1999; Revercomb et al. 2003; Westwater et al. 2003). Both radiosonde measurements and remotely sensed PWV also have significant applications in climate research (Revercomb et al. 2003) and in the calibration and validation of remote sensing instruments (Westwater 1997; Turner and Goldsmith 1999; Turner et al. 2003). For these studies, intercomparisons between different radiosonde types and different manufacturers as well as between various types of re-

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mote sensors are quite useful in evaluating accuracies and in discovering possible inconsistencies in the measurements.

Many comparisons of radiosondes and remote sensors have been conducted in the midlatitudes (Revercomb et al. 2003; Wang et al. 2003) and in the Tropics (Westwater et al. 2003; Wang et al. 2002). However, there is a dearth of radiosonde and remote sensor comparisons for Arctic locations. This is especially important in climate modeling for PWV < 3 mm when infrared radiance in normally opaque regions becomes partially transparent and structure in the frequency spectrum becomes apparent. As a first step in evaluating a variety of radiometers in the Arctic in conditions of low PWV, in March 1999, an intensive operating period (IOP) was conducted at the U.S. Department of Energy's Atmospheric Radiation Measurement Program's (ARM) "Great White" (GW) field site near Barrow, Alaska (Racette et al. 2005). Because of a limited number of radiosondes, many questions were left unanswered about the accuracy of radiometric remote sensors. In particular, at that time, ARM radiosondes were launched only once per day and at asynoptic times, making comparisons with the synoptic launches of the U.S. National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS) difficult. In addition, Vaisala RS80 radiosondes were also launched by ARM, and these radiosondes are known to have a dry bias, at least at mid- and tropical latitudes (Revercomb et al. 2003; Turner et al. 2003; Westwater et al. 2003; Wang et al. 2002). To better understand these and other issues, the 2004 North Slope of Alaska (NSA) Arctic Winter Radiometric Experiment Water Vapor Intensive Operational Period (WVIOP04) was conducted at the Great White from 9 March to 9 April 2004. The basic goals of the experiment were to examine the relative sensitivity of millimeter wavelength radiometers to conventional microwave radiometers, to demonstrate a new NOAA instrument and its associated calibration techniques, and to compare microwave and millimeter forward models for radiative transfer. A description of the experiment is given by Westwater et al. (2004), and initial results are given in Mattioli et al. (2005b), Cimini et al. (2005), and Westwater et al. (2005). In this experiment, several radiosonde observations (raobs) by different types of sensors were taken and several remote sensing instruments were operated. This paper presents the results of the comparisons of radiosonde measurements of temperature and relative humidity profiles as well as the comparison of measurements of PWV by radiosondes, a dual-channel microwave radiometer (MWR), a microwave radiometer profiler (MWRP), and a global positioning system (GPS) receiver. Our results represent the first systematic comparisons of the above remote sensors and radiosonde systems for cold (from 0° to −40°C in surface temperature) and dry (PWV from 0.08 to 1.5 cm) conditions.

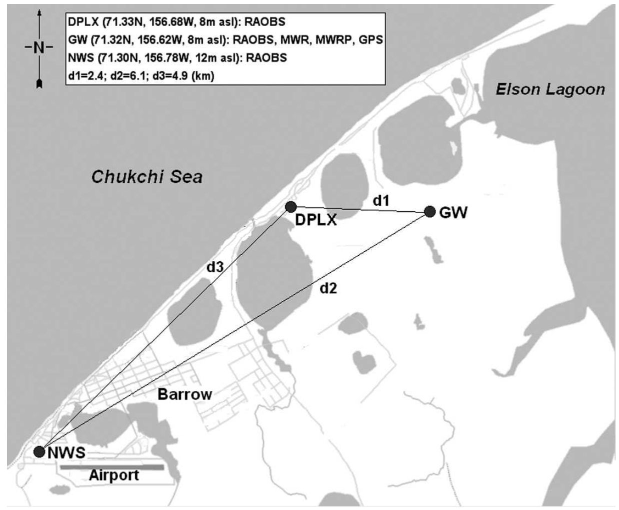

FIG. 1. Location and coordinates of ARM GW, ARM DPLX, and NWS upper-air station in Barrow, AK.

2. Radiosonde launch strategy

In the 2004 IOP, three different humidity sensors were deployed from three separate locations near Barrow. ARM Operational Balloon Borne Sounding System (BBSS) radiosondes were launched daily at 2300 UTC [2 P.M. Alaska standard time (AKST)] at the Great White. In addition, at the ARM Duplex (DPLX) in Barrow, 2.4 km to the west of GW, BBSS radiosondes were launched 4 times daily (0500, 1100, 1700, and 2300 UTC). Data from synoptic radiosondes from the NWS (1100 and 2300 UTC) were also archived. The NWS site is in Barrow, 4.9 km to the southwest of GW. Finally, during clear conditions, eight dual-radiosonde launches (see section 3c) were conducted at the ARM Duplex. The location and coordinates of the three raob sites are shown on the map in Fig. 1. This collection of almost simultaneous and nearly collocated raobs allowed us to compare various aspects of temperature and humidity measurements.